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PATENT
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CAMERA DOLLY

This application is a Continuation-in-Part of Serial No. 09/055,012, filed April 3, 1998, now pending, and incorporated herein by reference.

BACKGROUND OF THE INVENTION

The field of the invention is camera dollies and camera pedestals.

In the production of motion pictures, the motion picture camera must often be moved from one position to another. The camera movements may require a change in camera position, camera angle, or camera elevation. The camera movement must be performed smoothly, as even small amounts of vibration of the camera can result in unsatisfactory filming, due to shaky or erratic recorded images. For certain film sequences, the camera must be held in a fixed position. In other film sequences, the camera must be continuously and rapidly moved to follow an action or moving sequence. Similar requirements must often be met when using television cameras.

Camera dollies and pedestals have long been used to support and move motion picture cameras. Typically, a camera dolly has four wheels or pairs of wheels on a chassis having a generally rectangular wheel base. The wheels may be attached to the chassis via articulated legs, or the wheels may be directly pivotably attached to the chassis.

The camera dolly is pushed over the floor by dolly operators. During filming on sand, grass, or other uneven surfaces, the dolly may be placed on rails or tracks to provide an even and smooth rolling surface. The dolly wheels may be adapted for both ground and track

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operation, or separate ground and track wheels may be supplied as accessories, to be installed on the dolly as needed. Larger camera dollies may be self-propelled using electric motors and on-board batteries. Camera pedestals provide similar functions and are used primarily in television studios.

Most camera dollies and pedestals are provided with an arm or telescoping column, to raise and lower the camera. The arm maybe a beam arm, or a hinged holding arm. The arm or column is driven hydraulically, pneumatically or electrically. Various accessories, such as pan heads, tilt heads, risers, extensions, remote control camera heads, etc. may be used to move and position the camera as needed. Seats are often attached to camera dollies to accommodate the cameraman. Push bars and handles may be installed to make it easier to push or carry a camera dolly.

Many camera dollies have steering systems which steer the wheels of the dolly, similar to an automobile. A steering bar or handle at the back end of the dolly is turned by the dolly operator to steer the dolly wheels, typically using a series of chains or belts and sprockets contained within the dolly chassis. The camera is normally mounted towards the front end of the dolly.

For added versatility, the camera dolly should be capable of both "conventional" steering and "crab" steering. Conventional or corrective steering refers to a steering mode where the front wheels of the dolly are locked in to a straight ahead position, while the rear wheels of the dolly are controlled by the steering system and are steered at corrected or adjusted steering angles (or vice versa). This mode may also be referred to as 2-wheel

corrective steering. As the dolly turns and travels along a curved path, the inside wheel travels on a radius less than that of the outside wheel, as the outside wheel is spaced apart further from the center of the curved path than the inside wheel. As a result, for proper steering, the inside wheel must turn more sharply than the outside wheel.

A similar requirement is found in automobiles, which have steering linkages which attempt to provide corrective steering. However, in automobiles, the corrective steering is not precise. As a result, when automobiles make sharp turns, the tires may scrub somewhat over the payment. The scrubbing generates the screeching or skidding sounds often heard as an automobile makes a sharp turn, even at a low speed. The scrubbing results because each front wheel is not precisely turned to the correct steering angle needed for the automobile to travel on the curved path. However, in automobiles, this small amount of tire scrubbing during sharp turns is acceptable.

In contrast to automobiles, scrubbing and screeching tires are entirely unacceptable for camera dollies. Camera dolly operation must be silent to avoid interfering with the soundtrack of the motion picture or television production, where even an intermittent or relatively low level of equipment noise will be disruptive and unacceptable. Tire scrubbing also makes a camera dolly more difficult to push, due to increased rolling friction. Many camera dollies accordingly have included steering angle correctors or transmissions, for example, as described in U.S. Patent No. 4,003,584, or 5,174,593.

In these camera dollies, more precise steering angle correction is provided for the conventional steering mode, using cams, moving offset plates, or other mechanical devices

intended to achieve correct geometrical steering. That is, these types of steering angle correctors cause the rear wheels of the dolly to more closely track the perfect geometric steering pattern defined by the specific tread width and wheel base of the dolly and a specific turning radius. The front wheels, which are locked into the straight ahead position, do not participate in steering (in the conventional steering mode) and do not need any steering angle correction (similar to the rear wheels of an automobile). The conventional steering mode is often used to simply relocate or position the dolly. Conventional steering mode also is used, for example, when multiple panning or camera turning shots are needed. These types of filming shots might occur during an action sequence where the subject is moving through a hallway having curves or turns.

As is well known in the camera dolly field, to achieve perfect steering geometry in conventional steering mode, the rear wheels must be oriented so that their axes of rotation intersect at a point on a line passing through the center lines of the front wheels. Deviation from these steering angles causes the tires to scrub, if even only slightly, rather than rolling freely. This principle is illustrated in Fig.47A where X and Y are the rear wheels of the dolly, and K and L indicate the tread and wheelbase respectively, and is explained in detail in U.S. Patent No. 5,174,593, incorporated herein by reference.

Most camera dollies are also capable of crab steering, which is a steering mode where all wheels of the dolly are steered to the same angle. The crab steering mode, which is commonly used more often than the conventional steering mode, allows the dolly to move forward or back, left or right, or at any angle, as shown in Fig. 44, without changing the

"azimuth" camera angle of the camera, or the angular position of the dolly. Accordingly, the crab steering mode offers great versatility. When the subject being filmed is distant from the camera lens, the dolly may be shifted laterally, using the crab steering mode, without significantly affecting the camera angle.

In crab steering mode, no steering angle correction is needed or provided. All of the wheels are coupled via chains or belts to the steering bar or handle, and all of the wheels turn together. The wheel rotation axes of all the wheels always remain parallel to each other. The steering angle of each wheel is identical and tracks the steering angle of the steering handle or bar. A shift mechanism is provided to shift between crab and conventional steering modes, depending on the needs of the camera movement sequence. In existing dollies, shifting between steering modes is achieved through movement of a lever, a shift pedal, or other device.

Some camera dollies also provide a round steering mode. In the round steering mode, all of the dolly wheels are turned by the steering system. The front and rear wheels along each side of the dolly are turned in equal, but opposite direction, as shown in Figs. 43 and 47B. The wheel rotation axis of all the wheels intersect at approximately a common point, located on a lateral center line of the dolly. This allows the dolly to rotate about its geometric center or another point on the lateral center line. Round steering allows the dolly to be turned around in a very tight space as the dolly turns within its own length. In contrast, with conventional steering, almost twice as much space would be needed to turn the dolly around. Round

steering must also be "corrective" in that for proper round steering, the wheel angles must be adjusted to compensate for the steering geometry of the dolly.

While certain camera dollies have previously provided conventional, crab and round steering modes, these dollies generally required multiple operator movements to shift between these steering modes. These shifting movements have required the dolly operator to remove at least one hand from the steering bar to shift between modes, thereby making it difficult or impossible for the dolly operator to continuously and accurately move and steer the dolly, while simultaneously shifting between shifting modes. As split second timing is often required during filming or taping, to appropriately move and position the camera, even the short delay in moving a hand from the steering bar, to a shift lever, can be a significant disadvantage. In addition, unless the operator is highly experienced, the operator will have to look down to locate the shift lever. The operator is therefor unable to continuously watch the dolly, or look for cues, marked floor positions, etc. As a result, dolly operation can be difficult.

In addition, the steering systems in virtually all camera dollies which provide steering and shifting between steering modes, are integrally built in to the dolly, and can be replaced or modified only with substantial difficulty. Accordingly, when a steering system is damaged or otherwise requires service, the dolly becomes unavailable for use until the service or repair can be made.

Accordingly, there remains a need for an improved camera dolly, and for a camera dolly having an improved steering system.

SUMMARY OF THE INVENTION

To these ends, a camera dolly includes a camera steering unit which provides for shifting between corrective or conventional steering, crab steering, and round steering, without the operator removing the hands from the steering bar. Preferably, the steering unit has a first transmission and a second transmission linked together for simultaneously shifting between conventional, crab and round steering modes. A differential advantageously has sprockets, which move to offset positions for conventional and round steering. Chains or belts extend around sprockets on the transmissions and differential, and directly or indirectly to the wheels of the dolly. The first and second transmission and the differential, along with other components form a conventional mode steering system, a crab mode steering system, and a round steering system, each selectable with a single handle movement. Linkages preferably control shifting of the components of the differential, and also control movement of dynamic idlers, to maintain appropriate chain tension or belt tension. The camera dolly may be quickly and easily shifted between steering modes with both of the operator's hands remaining on the steering bar, and without the need for the operator to look or feel for a shifting lever.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and features of the invention will become apparent from the following detailed description taken in connection with the accompanying drawings, which disclose the preferred embodiment of the invention. It is to be understood, however, that the drawings are

designed for the purpose of illustration only, and are not intended as a definition of the limits of the invention.

In the drawings, wherein similar reference characters denote similar elements throughout the several views:

Fig. 1 is a perspective view of the present camera dolly;

Fig. 2 is a back and right side perspective view of the steering system of the dolly shown in Fig. 1;

Fig. 3 is a front and right side perspective view thereof;

Fig. 4 is a front and left side perspective view thereof;

Fig. 5 is a section view of the T-bar steering handle of the dolly of Fig. 1;

Fig. 6 is a top view taken along line 6-6 of Fig. 5;

Fig. 7 is an exploded perspective view of the steering system with the top plate and other components removed for clarity of illustration;

Fig. 8A is plan view of the top plate shown in Fig. 2;

Fig. 8B is a plan view of the bottom plate shown in Fig. 2;

Fig. 9 is a schematic perspective view of the arrangement of the ten chains of the steering system as viewed from the steering position or back of the camera dolly;

Fig. 10 is a plan view of the steering system installed in a camera dolly, with the top plate removed for clarity of illustration;

Fig. 11A is a plan view of the right conventional chain;

Fig. 11B is a plan view of the differential middle sprocket chain;

Fig. 11C is a plan view of the right rear chain;

Fig. 12 is a plan view of the right round chain;

Fig. 13 is a plan view of the left round chain;

Fig. 14 is a plan view of the first or left crab chain;

Fig. 15 is a plan view of the second or right crab chain;

Fig. 16 is a plan view of the front left chain;

Fig. 17 is a plan view of the left conventional chain;

Fig. 18 is a plan view of the front right chain;

Fig. 19A is a partial section view of the steering system showing the front and rear transmissions (in the conventional or corrective steering mode);

Fig. 19B is an enlarged partial section of the rear transmission;

Fig. 20 is a rear elevation view, in part section, of the steering system installed in a dolly chassis;

Fig. 21 is an exploded perspective view of the differential;

Fig. 22 is a section view of the differential;

Fig. 23A is a plan view of the differential middle plate;

Fig. 23B is a side view thereof;

Fig. 23C is a plan view of the differential middle plate retainer ring;

Fig. 23D is a section view thereof;

Fig. 24 is an exploded perspective view of the front transmission distributor;

Fig. 25 is a side elevation view of certain shift links and active idlers;

Fig. 26 is an enlarged section view of an active idler;

Fig. 27 is a partial plan view showing the arrangement of the links block, shift lock, and indent wheel of the rear transmission;

Fig. 28 is a right side perspective view of the links block;

Fig. 29 is a left side perspective view thereof;

Fig. 30 is a plan view of the links blocks and attached links;

Fig. 31 is a cross sectional elevation view of the links block and attached links;

Fig. 32 is a perspective view of the links block housing;

Fig. 33 is a bottom perspective view of the steering system shown in Fig. 2;

Fig. 34A is a bottom view looking up of the leg position shift links shown in Fig. 33;

Fig. 34B is an isolated plan view of a link and slot arrangement as shown in Fig. 34;

Fig. 34C is a partial top view of the leg position shift handle;

Fig. 34D is a side view thereof;

Fig. 35 is a side elevation view thereof taken along line 35-35 of Fig. 34A;

Fig. 36 is an isolated plan view of the links block and shift lock mechanism;

Fig. 37 is a side elevation view thereof;

Fig. 38 is a left side end view thereof;

Fig. 39 is a schematic plan view showing the steering system in the conventional or corrective steering mode;

Fig. 40 is a schematic plan view showing the steering system in the crab steering mode;

Fig. 41 is a schematic plan view showing the steering system in the round steering mode;

Fig. 42 is a schematic layered view showing the connections between the links and sprockets;

Fig. 43 is a schematically illustrated plan view showing the dolly steering in round steering mode;

Fig. 44 is a schematically illustrated plan view of the dolly steering in crab mode;

Fig. 45 is a schematically illustrated plan view of the dolly steering in conventional or corrective steering mode;

Fig. 46 is a schematic illustration showing alternate leg positions; and

Figs 47A and B are geometric constructions illustrating principles of corrective or conventional and round steering; and

Fig. 48 is a schematic diagram of a dolly having a servo assist steering system.

DETAILED DESCRIPTION OF THE DRAWINGS

THE DOLLY CHASSIS

Turning now in detail to the drawings, as shown in Figs. 1-4, a camera dolly **30** has a chassis **32**. A hinged or articulating arm 34 is supported on the chassis **32**. A camera platform **38** on top of the arm **34** supports a motion picture, video, or television camera **36**. The dolly **30** has front left and right legs **40** and **41**, and rear left and right legs **42** and **43** pivotally attached to the chassis **32**.

THE STEERING HANDLE

A T-bar handle **44** extends up from the back end of the chassis **32**. Inside of the chassis **32**, the lower end of the T-bar handle **44** connects to a steering unit **50**, which can steer all of the wheels of the dolly and shift to select steering modes.

Turning to Figs. 5, 6, and 27 the T-bar handle **44** includes a horizontal handle bar **52** having a pinion gear sector **54**. The handle bar is pivotally mounted on a handle housing **55** supported on a handle tube **56**. A rack bar **58** extends within the handle tube **56**. Rack teeth **60** on the rack bar **58** mesh with gear teeth on the pinion gear sector **54**. A top end of a connecting rod **62** is threaded into the rack bar **58** and extends down through the bottom on the handle tube **56**. The bottom end of the connecting rod 62 is threaded into a pin plate rod **162** in the rear transmission **104**, as shown in Fig. 19A. A tube cup **64** having a threaded lower end **65** is slidably positioned around the handle tube **56**, and used to attach the handle to the steering unit **50**. Wedge keys **67** on a drive sleeve **68** assure positive locking to steering system **50**. (Fig. 5).

The T-bar handle **44** shown in Fig. 5 and 6 is used for steering the dolly and for shifting the steering unit **50** of the dolly **30** between different steering modes. The steering unit **50** will now be described in detail, followed by an explanation of the interconnection and operation of the handle **44** and steering unit **50**.

THE STEERING UNIT

The steering unit **50** is generally shown in Figs. 2-4 and 7-20. The top plate **70**, separately shown in Fig. 8A, has been removed from Fig. 7, for illustration purposes. Referring to Fig 7, the steering unit **50** includes a front transmission **102** and a rear transmission **104** supported on a bottom plate **72**. The bottom plate **72** is separately shown in Fig. 8B. A rear transmission distributor **116**, and a front transmission distributor **115** are rotatably attached between the top and bottom plates **70** and **72**. A differential **108** is also attached to the bottom plate **72**. Chains extend around various sprockets and idlers and ultimately control the steering angle of the wheels.

THE DOLLY SPROCKETS

As shown in Fig. 2, with the right rear wheel shown as representative, the wheels **45** of the dolly are rotatably supported on a king pin **47**. In the embodiment shown, a pair of spaced apart dihedral wheels are shown, although other wheel arrangements, including single wheels, may be used. A king pin sprocket **49** is fixed to the top end of the king pin **47**. A leg chain**51** connects the king pin sprocket **49** with a lower axle sprocket **55** on an axle **53**. A right drive sprocket **57** is irrotatably fixed to the axle **53.** A right conventional chain **80** connects the right drive sprocket into the steering system **50**. A lower right rear sprocket **59** is also irrotatably fixed with set screws (which allow rotational adjustment during manufacture or maintenance) to the axle **53** and connects into the steering unit **50** via a right rear chain **83**, as

further described below. On the rear left leg **42**, as shown in Fig. 4, a left conventional chain **92** extends around a left rear drive sprocket **118**.

Referring to Figs. 2 and 9, inside the chassis at the front legs **40** and **41**, a front left chain **90** and a front right chain **94** engage a front left drive sprocket **126** and a front right drive sprocket **128**, respectively, which drive the steering of the front wheels.

THE STEERING UNIT SPROCKETS

Turning briefly to Figs. 19A and 19B, the rear transmission **104** has a top sprocket **142**, a first center sprocket **144**, a second center sprocket **146**, and a lower sprocket **149**. The front transmission **102** similarly has a top sprocket **172**, a center sprocket **174**, and a lower sprocket **176**.

Referring momentarily now to Figs. 20 and **24**, the front transmission distributor **115** has a top sprocket **190**, a middle sprocket **192**, and a lower sprocket **194**. Similarly, the rear transmission distributor **116** has a top sprocket **120**, a middle sprocket **122**, and a lower sprocket **124**. All three sprockets on the front transmission distributor **115,** and on the rear transmission distributor **116,** are locked together (except during assembly or adjustment). In contrast, the sprockets of the front **102** and rear **104** transmissions may or may not be locked together, depending on the steering mode selected. The front and rear transmission distributors **115** and **116** may be the same, except for the vertical positions of their sprockets. A distributor plate **200** under the lower sprocket **194** helps to even out the clamping force of the bolts **197**.

Referring momentarily to Figs. 21 and 22, the differential **108** includes top, middle and bottom sprockets **110, 111,** and **112**, which turn together, and can be aligned or offset from one another, as required for different steering modes.

THE CHAINS AND IDLERS

Setting aside momentarily the various other components and details shown in Figs. 7-20, the chains in the steering unit **50** are first separately described and shown to provide a better understanding of the steering system **50**. The terms "conventional", "crab", and "round" are used below for convenience only, and are standard terms of art in the field of camera dollies. These terms as used below generally refer to the steering mode which a chain is primarily involved with. The term "corrective" steering means the same as "conventional" steering. These terms do not describe any characteristic of the chain itself. Indeed, all ten of the chains in the steering unit **50** are preferably identical, except in length. The chains are preferably pre-stretched and lubricated. (The chains within the articulating legs **40-43** and chassis **32** are not part of the steering unit itself, in that the steering unit **50** can be removed or retrofitted from the dolly **30** without removing them from the dolly.)

The Figures are drawn in proportion to reflect the preferred size, shape and positional relationships of various components. The terms right and left refer to the operator's hands when operating the dolly in the usual way, i.e., standing or walking behind the dolly while facing forward with the hands on the T-bar. Each of the ten chains is shown as used in Fig. 9 and then separately in Figs. 11-18, for clarity of illustration. Some of the fixed idlers are omitted from

Fig. 9 to better show the certain design features. The fixed idlers are rotatably attached to the top or bottom plate **70** or **72**, or to both plates, and are shown in other Figures.

Turning to Figs. 9 and 11A, a right conventional chain **80** extends around the top sprocket **110** on the differential **108**, around a conventional chain rear active idler **99** and around the right rear drive axle sprocket **57**. A fixed idler **100** tensions the chain **80** between the active idler **99** and sprocket **57**. A conventional chain front active idler **76** tensions the chain **80** between the sprocket **57** and the sprocket **110**. The movement of the active idlers **99** and **76** is driven by movement of the various links coordinated with the movement of other components of the steering unit **50**, to keep tension on the chain **80** despite movement of the sprockets around which chain **80** passes, during shifting between steering modes.

As shown in Fig. 11B, a differential middle sprocket chain **81** extends around the first center sprocket **144** of the rear transmission **104**, around a middle differential sprocket chain rear active idler **75**, and around the middle differential sprocket **111**. A middle differential sprocket chain front active idler **77** tensions the chain **81** between sprockets **111** and **144**. The active idlers **75** and **77** similarly maintain tension on the chain **81**.

As shown in Fig. 11C, a right rear chain **83** extends around the lower sprocket **149** of the rear transmission **104** and around the lower right rear sprocket **59** on the axle **53**. The chain **83** is tensioned by fixed idlers **78** and **79**.

As shown in Figs. 9 and 12, a right round chain **82** extends around the lower sprocket **146** on the rear transmission **104**, and around fixed idlers **96** and **98**. The back or reverse side of the right round chain **82** engages the center sprocket **122** on the rear transmission distributor

116. Due to the short sector angle of engagement, a chain retainer **326** is provided to prevent the chain **82** from riding up and over the sprocket teeth during high loads.

Referring to Figs. 9 and 13 a left round chain **84** extends around a lower sprocket **176** on the front transmission **102**, and around a fixed idler **85**. The back side of the chain **84** wraps partially around a lower sprocket **194** on the front transmission distributor **115**. A second chain retainer **324** is positioned adjacent to the sprocket **194**.

As shown in Figs. 9 and 14, a left crab chain **86** extends around the top sprocket **172** on the front transmission **102**, and around the top sprocket **190** on the front transmission distributor **115**.

As shown in Figs. 9 and 15, a right crab chain **88** extends around the top sprocket **120** of the rear transmission distributor **116**, and around the top sprocket **142** of the rear transmission **104**.

Referring to Figs. 9 and 16, a front left chain **90** extends around the center sprocket **192** of the front transmission distributor **115**, passes around fixed idlers **95** and **97**, and extends forward within the chassis to a front left wheel drive sprocket **126**. Similarly, as shown in Figs. 9 and 18, a front right chain **94** extends around the lower sprocket **124** on the rear transmission distributor **116**, around fixed idlers **105** and **101**, extends forward within the chassis **32** and around the front right wheel drive sprocket **128**, which is shown in Fig. 2.

Turning to Figs. 9 and 17, the left conventional chain **92** extends around the left rear wheel drive sprocket **118** and around the center sprocket **174** of the front transmission **102**.

The chain **92** also passes around the lower sprocket **112** of the differential **108**, with the back side of the chain **92** also engaging a fixed idler **93**.

The ten chains described above connect the various components of the steering system **50**. However, the steering unit **50** is self-contained, except for chains **80**, **83**, **92**, **90** and **94**, which engage the wheel drive sprockets **57**, **59**, **118**, **126** and **128** respectively of the dolly **30**. As a result, when the steering unit **50** is installed into the dolly **30**, only chains **80**, **83**, **92**, **90** and **94** need to be appropriately connected. This facilitates fast and relatively easy installation and removal of the steering unit **50** as a unit into and out of the dolly **30**.

While the steering unit **50** is shown using chains and sprockets, toothed belts may equivalently be used. The idlers described above as being "fixed" idlers, are fixed in the sense that after the steering unit **50** is installed and adjusted, the fixed idlers are moved (in slotted holes) and then tightened and fixed in place. The fixed idlers rotate, but do not translate or shift during operation of the steering system. In contrast, the four active idlers described above both rotate and change position as the steering unit **50** is shifted between different steering modes, to maintain proper tension in chains **80** and **81**. The fixed idlers have sprockets rotatably attached to standoffs which are secured to the top plate **70** or bottom plate **72** of the steering unit **50**. The active idlers **99**, **76**, **75** and **77** are sprockets rotatably attached to movable links.

THE REAR TRANSMISSION

Referring to Figs. 19A and 19B, the rear transmission **104** includes a pin plate rod **162** which is threaded into and turns with the handle tube **56**. An upper pin plate **168** and a lower pin plate **160** are attached to the pin plate rod **162**. The top sprocket **142**, first center sprocket **144**, second center sprocket **146** and lower sprocket **149** of the rear transmission **104** are mounted on bearings **148** supported on a rear transmission axle **140**. An indent wheel **143** is fixed to and/or integral with sprocket **149**. The indent wheel **143** is round and has two indents **71** on opposite sides of the perimeter of the wheel **143**, as shown in Fig. 9.

The pin plate rod **162** extends vertically upwardly through a bore in the rear transmission axle **140**. Referring to Fig. 19A, the rear transmission axle **140** is rotatably mounted on bearings **138** within a receptacle **136** extending up from the top deck **132** of the chassis **32**, and within an upper transmission housing **130** and a lower transmission housing **165**. A shoulder cap **175**, is attached to the rod **162** by a pin **167**, slidably movable along the axle **140**. The rear transmission axle **140** turns with the handle tube **56**. The pin **167** extends through a slot **166** at the upper end of the pin plate rod **162**, to attach the rod **162** to the shoulder cap **175** yet allow it to shift vertically. A bushing **170** reinforces and stabilizes the pin plate rod **162** via the guide pin **164**. A spacing sleeve **139** spaces the bearings **138** apart. A threaded sleeve **145** is pinned onto rear axle **140**.

The sprockets **142, 144, 146,** and **149** in the rear transmission **104** and the indent wheel **155**, each have a pair of diametrically spaced apart pin clearance holes **169**. Referring to Fig. 19B and 19A, a stack-up of nine pairs of shift pins **150-158** of specific varying lengths extend

through the clearance holes in the sprockets. The first shift pin **150** is attached to the top of the lower pin plate **160** by screws **177**. The other shift pins **151-158** are vertically aligned or stacked-up within the rear transmission housing **165** and upper transmission housing **130** and/or the sprockets **142, 144, 146** and **149** in the rear transmission **104**.

The first center sprocket **144** is keyed or pinned to the rear transmission axle **140**, and therefore always turns with the axle **140** and steering handle **56**. The other sprockets in the rear transmission **104** can be free spinning or locked into connection with the first center sprocket **144**, depending upon the vertical position of the shift pins **150-158**, as driven by up and down movement of the lower pin plate **160** and upper pin plate **168**. Fig. 19A shows the front and rear transmissions **102** and **104** in the conventional steering mode.

THE FRONT TRANSMISSION

Referring still to Fig. 19A, the front transmission **102** has a similar arrangement of sprockets and pins, but without the fourth and lower sprocket **149** and indent wheel **143**. Specifically, the center sprocket **174** is part of or attached (i.e., pinned or welded), to a front transmission axle **178** rotatably supported by bearings **148** with shift rod **180** slidably passing through. Shift rod **180** shifts vertically during shifting of the steering unit **50**, but does not rotate. The top sprocket **172** and bottom sprocket **176** are rotatably mounted on the axle **178** via bearings **148**. A stack-up of shift pins **181-185** extends through the front transmission housing **179** and upper housing **106** and the sprockets **172, 174** and **176** in the front transmission, similar to the design described above for the rear transmission.

A raised cover **186** is provided as part of the top deck **132** of the chassis **32**, to provide vertical clearance for the top ends of the fifth shift pins **185**. The first shift pins **181** are attached to a lower pin plate **187**. The fifth shift pins **185** are attached to an upper pin plate **189**. The lower pin plate **187** and the upper pin plate **189** are bolted to the ends of the shift rod **180** via end bolts **191**. The lower end bolt has a grooved cap **298** attached to a transmission linkage **236** (further described in connection with Figs. 33 and 34 below) which causes the front and rear transmissions to shift together. As the lower plate **187** is pushed up or pulled down by operation of the transmission linkage **236**, the shift pins are correspondingly pushed up or pulled down through the clearance holes in the sprockets, to engage or disengage the top sprocket **172** and lower sprocket **176** to the center sprocket **174**, which is permanently attached to the front transmission axle **178**. The shift rod **180** can slide vertically within the bore in the front transmission axle **178**, to allow shifting to take place.

While the front and rear transmissions are shown here as separate, they may also be combined into a single transmission. This would require more height, but less width or depth for the steering unit.

THE FRONT AND REAR TRANSMISSION DISTRIBUTORS

Turning to Figs. 9, 20 and 24, the front transmission distributor **115** is made up of the front distributor top sprocket **190**, center sprocket **192**, and lower sprocket **194**. During operation of the steering system **50**, all three of these sprockets are locked together and turn as a unit. The bottom sprocket **194** is substantially flat. The center sprocket **192** has a short shaft

section **193**. The top sprocket **190** has a long shaft section **195**. Adjusting bolts **197** pass through clearance holes or slots in the lower sprocket **194** and center sprocket **192** and thread into a land at the lower end of the long shaft section **195**. Tool access openings **199** are provided through the lower chassis plate **201** (which supports the lower plate **72** of the steering system **50**). This allows the three sprockets to be appropriately adjusted with respect to each other, and then locked together by tightening the adjusting bolts **197**. The three sprockets are rotatably supported on a distributor hub **203** by bearings **148**. The rear transmission distributor **116** has a similar design, although the vertical position of the center sprocket **122** and bottom sprocket **124** are vertically displaced (above) the center and lower sprockets on the front transmission **115**.

Referring still to Fig. 20, the steering system **50**, when installed in the dolly **30**, is enclosed by the dolly chassis **32**, specifically, by the cover plate **132**, the chassis side walls **133**, and the lower chassis plate **201**. The lower chassis plate **201** which is attached to the side walls **133**, has a cut-out to provide clearance for the transmission linkage **236**.

<u>THE DIFFERENTIAL</u>

Turning now to Figs. 21, 22, 23A-23D, the differential **108** has a top differential sprocket **110** mounted on a ball bearing **228**. A stud **229** extends up from the bearing **228** and is attached to a link. A top differential plate **205** is irrotatably attached to or integral with the top sprocket **110**. A slot **210** having a rectangular cross section is centrally located on the underside of the plate **205**.

A center roller plate **222** has a roller **218** mounted on a roller post **220** on the top surface of the plate **222**. The plate **222** is irrotatably attached to the differential center sprocket **111**, which in turn, is irrotatably attached to an inner race plate **206**. As shown in Fig 21,, bolts 113 pass through clearance holes in the sprocket 111 and thread into tapped holes 202 in the plate 222. A roller post **220** extends down from the underside of the inner race plate **206**, with a roller **218** mounted on the roller post **220**. The inner race plate **206** is rotatably mounted via ball bearings within a center differential plate **209**. A cap plate **219** holds the ball bearings in place. The center differential plate **209** has a first arm **214** and a second arm **215** which are attached to links.

The bottom differential sprocket **112** is mounted on a bearing **228** supported on a stand off **224** which is bolted to the bottom plate **72**. A bottom differential plate **207** is irrotatably attached or fixed to the lower differential sprocket **112**. The bottom differential plate **207** includes a slot **210** in its upper surface. The rollers **218** roll within the slots **210**. As a result, torque can be transmitted between the sprockets **110, 111,** and **112**, and the sprockets can be offset from one another as shown in Figs. 39-41, to provide corrective and round steering. Referring to Fig. 23A, the center differential plate **209** has a lip **223**, on one side. The lip **223** slides within a horizontal slot in a stand off, to resist out of plane movements when the steering system is under heavy loads.

Alignment holes **212** pass through the top differential plate **205**, roller plate **222**, center differential plate **209** and the lower differential plate **207**. During manufacture and assembly of the differential **108**, these components are aligned and held into alignment by an alignment

pin **213** which is temporarily placed in the alignment holes **212**. The center sprocket **111** and lower sprocket **112** can be turned relative to the inner race plate **206** and lower differential plate **207** respectively, by loosening bolts which, in use, clamp those sprockets rigidly in place. With the alignment pin **213** in place, the bolts **113** are loosened, the sprockets **111** and **112** are turned slightly for appropriate chain tension, and the bolts **113** retightened to lock the center sprocket **111** onto the inner race plate **206** and to lock the lower sprocket **112** onto the lower differential plate **207**.

THE LINKS

The steering unit **50** has a system of moving links. The links provide a mechanical connection between the steering handle, to change the offset of the sprockets of the differential, depending on the steering mode selected. The system of links also provides a mechanical connection between the steering handle and the four active idlers, so that as the steering system **50** is shifted between steering modes and the positions of the top **110** and center **111** differential sprockets change, proper chain tension is maintained on the chains going around those sprockets. The links provide coordinated movement between the steering/shift handle, the top and center differential sprockets, and the active idler sprockets. While other techniques may be used to maintain chain tension, the present system of links is preferred due to its precision and relatively compact size. The system of links provides coordinated movement of the top differential sprocket **110** (which in turn also displaces the center differential sprocket **111**) and the four active idler sprockets via five links attached to a pivoting links block **230**.

As shown in Figs. 28-31, the links block **230** is pivotally mounted on a housing **232** on needle bearings **278** supported on a vertical shaft **231**. The links block housing **232** has threaded upper and lower ends **264** and **266** (as shown in Fig. 32) which are secured onto the top plate **70** and the bottom plate **72**. The shaft **231** extends through a bore **238** in the links block **230**.

Five links of the steering system are pivotally pinned onto five arms of the links block **230**. Referring to Figs. 7 and 31, a top link **260** is pivotally pinned to the top arm **262** of the links block **230** and extends diagonally rearwardly to the conventional chain rear active idler sprocket **99**. As shown in Fig. 25, sprocket **99** is rotatably attached to a top swing link **270** which is rigidly attached to a pivot post **271** supported by a pivot post housing **273** extending down from the top plate **70.**

Referring again to Figs. 7 and 31, a top differential sprocket link **250** is pivotably pinned or attached to the second arm **268** on the link stand **230** and extends diagonally left to the differential **108** where it is pivotally attached to the stud **229** on the differential, coaxial with the top differential sprocket **110**, as also shown in Fig. 25. Referring to Figs. 7 and 25, one end of a step link **248** is also pivotally attached to the stud **229** under the top sprocket link **250**. The step link **248** is pivotably supported on a stand off **252** attached to the top plate **70**. The other end or arm of the step link **248** is pivotally attached to one end of a connecting link **244.** The other end of the connecting link **244** is pivotally attached or pinned to the front end of an arm link **240**. The other end of the arm link **240** is pivotally attached to the first arm **214**

of the center differential plate **209**. The arm link **240** is also pivotably attached to a standoff **246** extending down from the top plate **70**.

Referring back to Figs. 28-31, a short link **280** is pivotally attached to a third arm **276** on the link stand **230.** The short link **280** extends rearwardly to the conventional chain front active idler sprocket **76**, as shown in Figs. 26 and 39-42. An idler link **272** extends from the idler sprocket **76** to a stand off **274** secured to the top plate **70**. The link **280** and sprocket **76** are not shown in Fig. 7 for clarity of illustration of other components. Sprocket **76** maintains appropriate tension on the conventional chain **80**, between the top differential sprocket **110** and the right rear drive sprocket **57**.

Referring once again to Figs. 28-31, a rear middle link **253** is pivotally attached to the fourth arm **254** on the links block **230**. As shown in Fig. 7, link **253** extends rearwardly and is pivotally attached to a generally center location of an idler step link **275**. The back end of the link **275** is pivotally attached to the stand off **274** (along with link **272**) secured through the top plate **70** and bottom plate **72**. The middle differential sprocket chain front active idler **77** is attached to the other end of the link **275**.

Referring once again to Figs. 28-31, a bottom link **256** is attached to a fifth arm (or location) **257** towards the bottom of the links stand **230**. The bottom link **256** extends diagonally rearwardly and is pivotally attached to a first end of a bottom pivot link **281**, as shown in Figs. 7, 25 and 42. The differential center sprocket chain rear active idler sprocket **75** is supported on the bottom pivot link **281**. The other end of the link **281** is pivotally attached to a stand off **283** secured to the bottom plate **72**.

The second arm **215** of the center differential plate **209** is pivotally attached to a plate link **245**, which in turn is pivotally supported on a shift lock housing **356** attached to the bottom plate **72**, as shown in Fig. 25. The pivotal attachments of the links are preferably made via pins, such as pin **247** extending through the plate link **245**.

Links **260, 280, 253** and **256** are provided only to maintain appropriate tension on the conventional chain **80** and on the differential center sprocket chain **81**, a function which can also be achieved using various other approaches.

The center differential plate **209**, together with the links **240**, **244**, **245, 248** and **250** form a parallelogram linkage which moves the top differential sprocket **110** and the middle differential sprocket **111** relative to the fixed-in-position bottom differential sprocket **112**, to provide the appropriate corrective steering angles to the rear wheels, when in conventional steering mode, and to all of the wheels when in round steering mode. The bottom differential sprocket **112** and bottom differential plate **207** are rotatably fixed in position on the standoff **224** attached to the bottom plate **72**. Accordingly, the bottom differential sprocket **112** can rotate about its center, but does not shift in position. The differential **108** therefore achieves all needed relative displacement between the top differential sprocket **110**, the center differential sprocket **111**, and the bottom differential sprocket **112**, by movement of the top differential sprocket **110** as driven directly by the link **250**, and by movement of the differential center plate **209**, as driven by the link **250** through links **248, 244** and **240**.

THE TRANSMISSION LINKAGE

Referring now to Figs. 7, 19 and 33-35, a transmission linkage **236** includes a linkage housing **290** bolted to the underside of the bottom plate **72**. A fork shaft **292** extends through a bore in the link housing **290.** Front and rear forks **294** and **302** respectively are attached to the ends of the fork shaft **292**. Pins **296** extend inwardly from both arms of the forks **294** and pivotally engage grooved caps **298** which are attached to the lower pin plates **160** and **187** on the rear and front transmissions. The interconnection between the pins **296** and the grooved cap **298** accommodates the relative vertical and slight horizontal movement between them as the forks rotate up and down, and also allows for rotational movement of the cap **298** in the rear transmission **104**, with steering movements. While the groove cap **298** on the rear transmission **104** rotates during steering, the groove cap **298** on the front transmission does not.

Referring to Figs. 7 and 33-35, the rear fork **302** includes an arm **304** linked to a ball clevis **306**. The ball clevis **306** is joined to the outer ends of a front link **308** and rear link **310**. The inner end of the front link **308** is pivotably attached to a stand **312** fixed to the bottom plate **72** via housing **290**. The inner end of the rear link **310** is pivotably attached to a driver link **314** pivotably attached to a base section **316** of the stand **312**. A connecting link **318** is pivotably attached to the driver link **314**, at the back end of the steering system **50** and to a lever **320**, towards the front of the steering system. The lever **320** is (welded) fixed to the bottom end of the vertical shaft **231** on the links block **230**.

As the rear fork **302** pivots up and down as the handle **52** is turned about axis B to shift steering modes, the arm **304** on the rear fork **302** drives the ball clevis **306** left to right, which causes the link **318** to move front to back in direction S. The link **318** in turn causes the links

block **230** to pivot. The links **308** and **310** form an over-center linkage so that, as the handle **52** twisted from the up position (corrective steering), to the center position (for crab steering), to the down position (for round steering), the link **318** first drives the links block clockwise (as viewed from above), and then counterclockwise by a greater amount, as shown in Figs. 39-41.

THE LEG POSITION COMPENSATOR

Camera dollies having articulated legs, such as the dolly **30** shown in Fig. 1, have preferred leg positions, for use in different applications. Referring to Fig. 46, these leg positions are:

Position No.	Front Legs	Back Legs
1	0°	0°
2	12°	12°
3	33°	33°
4	45°	45°
5	90°	0°
6	180°	0°

Other combinations of leg positions can also be used. However, when using other combinations, steering correction may not be as accurate, especially at very sharp turning angles. Consequently, these are the preferred leg positions. Changing leg positions changes the track width and wheelbase of the dolly (i.e., the lateral and longitudinal spacing between the kingpins). Accordingly, since the dolly geometry is changed, the correction of steering angles must also be changed, to maintain perfect or near perfect steering. The dolly **30** therefore has a leg position

compensator, described below, which compensates for changes between leg positions, to maintain near perfect steering geometry.

As best shown in Fig. 34A, the driver link **314** has a shift slot **334** on the top surface. The shift slot **334** curves on a radius equal to the length of the link **318**, between its attachment points. The slot **334** has an inboard hole **336** and an outboard hole **338**, at opposite ends of the slot **334**. A tapered link pin **332** is attached, by a press fit and is then welded to the top surface of the back end of the link **318**. The pin **332** extends downward to engage the hole **336** or **338**.

The inboard hole **336** is used when the legs of the dolly are in the Position Nos. 1 and 2, as shown in Fig. 46. The outboard hole **338** is used for leg Position Nos. 4, 5 and 6 as also shown in Fig. 46. Leg position No. 3 (front and rear at 33°), if provided, would use an intermediate hole between holes **336** and **338**. The 0°, 12° positions do not differ enough to require added correction.

To shift between the inboard and outboard holes (when the leg positions are changed), the handle **330** is lifted by about 0.2 inch to remove the pin **332** from the hole **336** or **338**. This shifting of the handle is preferably done while in the crab steering mode, because the dolly legs are more easily moved when in crab (as the wheels on the leg can be steering to track the arc traced out by pivoting a leg), and because the slot **334** and pin **332** position are selected so that shifting the handle **330** when in crab mode does not require movement of any other components. The handle is moved laterally. As this occurs, the pin **332** slides in the slot **334** until it drops into the other hole. Due to the radius of the slot, this movement occurs without turning the links block **230** when in the crab position.

As shown in Figs. 34A-D, the shift handle **330** is attached to the back end of the link **318**. The front end of the link **318** is attached to a pivot block **340** via a pivot pin **345**. The pivot block **340** is pivotably attached to the shift link **320**. A spring **342** biases the link **318** and handle downwardly, which maintains the pin **332** in its selected position, until the handle **330** is deliberately lifted up and shifted to another position, to compensate for a change in leg position. A stop bolt **364**, as shown in Figs. 34C and 34D, limits the downward movement of the link **318**, to prevent the pin **332** from engaging too tightly into holes **336** or **338**, and making handle movement more difficult.

When the steering is shifted between modes, the over center linkage **300** drives the link **318** in or out in the direction S shown in Figs. 34A, thereby pushing or pulling on the lever **320** and causing the links block **230** to pivot. This changes the offset provided by the differential. The offset compensates the steering apparatus for the change in the dolly wheel positions which occurs when the dolly legs are shifted to different positions.

As shown in Figs. 47A and B, as the tread dimension (lateral wheelbase) of the dolly increases (to a wider tread, in the 45° leg position), more steering angle correction is needed. If the wheel or leg position of a dolly is fixed, the steering system can nearly perfectly match the steering correction angles needed (without compensation or adjustment of the linkages), as these angles do not change. On the other hand, with the dolly shown in Fig. 1, the leg positions can be changed, resulting in a different wheelbase and tread dimensions. The ability to slightly adjust the amount of movement in the differential generated during shifting, by using the handle **330** to compensate for different leg positions, allows the steering system to provide near perfect steering angle correction, for almost all dolly leg positions. If desired, additional intermediate holes may

be provided in the slot **334** between holes **336** and **338**, to compensate for intermediate leg positions.

The shifting and compensation provided by moving the leg position handle **330** is independent of the steering mode shifting provided by the handle bar **52**. This ability to compensate for leg position is especially advantageous in round steering, where large amounts of steering angle correction are needed. While shifting between steering modes occurs frequently, changing leg positions is much less frequent. In camera dollies having a permanently fixed tread width, the leg position compensator is not needed and the steering system described above is simply used without it. It is, however, important to note that this adjustability allows the steering unit to be adaptable to most dolly designs.

THE SHIFT LOCK

As shown in Figs 27-29 and 36-38, the links block **230** preferably has an integral bottom sector plate **350**. The sector plate includes an arc or angle of about 90°. The vertical curved surface of the sector plate **350** has 5 vertical slots or grooves **351, 352, 353, 354** and **355**. A shift lock unit **370**, which is used to prevent inadvertent movement of the links block **230**, includes a housing **356** having a through bore **357**. A plunger **360** extends through the bore **357**. An end roller **358** on the plunger is biased into a constant engagement against the indent wheel **143**, at the bottom of the rear transmission **104**, via a compression spring **359**. The forward end **362** of the plunger **360** is angled and adapted to securely fit into any one of the grooves **351-355**. Ordinarily, the plunger is engaged into one of the grooves, thereby locking the links block **230** against any pivoting movement. The plunger **360** can only back out of a groove, and thereby

unlock the links blocks **230** to allow it to pivot, when one of the two opposite indents on the indent wheel, comes into alignment with the end roller **358** (with every 180° turning movement of the steering handle).

The grooves **351, 353,** and **355** are used respectively for round, conventional and crab steering, for leg position Nos. 4-6. The grooves **352** and **354** are used respectively for round and conventional steering, when the legs are in position Nos. 1 and 2. Position No. 3, if provided, would require two additional grooves on the sector plate **350**.

The steering unit shown in Figs. 39-41 is directly locked into a steering mode. This locking (of the links block **230**) is preferred to avoid any slight changes in the differential offset during dolly maneuvers that result in high loads on the steering system. The locking is also fully automatic. The steering system unlocks only when all of the wheels are straight ahead (at 0° or 180°), a condition where high loads are not ordinarily encountered, and the required position for shifting the front and rear transmissions.

DOLLY OPERATION

In use, the dolly **30** is ordinarily pushed from the back end with the user's hands on the handlebar **52**. Turning the handlebar **52** about the axis A in Fig. 2 correspondingly turns the center sprocket **144** in the rear transmission **104**, which is directly linked to the handle tube **56**. The center sprocket **144** then drives the remaining components in the steering system. Ordinarily, the dolly will be in crab mode, as a "home" position, as crab mode allows the dolly to move in any direction, without angulating (i.e., changing the azimuth) of the camera lens. Shifting between conventional, crab and round steering mode is achieved by pivoting the

handlebar **52** about the axis marked B in Fig. 2. With the handlebar **52** pivoted fully counterclockwise about axis B in Fig. 2, the rack bar **58** is pulled into the up position (for conventional steering) via the interaction of the pinion gear sector **54** on the rack teeth **60**, as shown in Fig. 5.

CONVENTIONAL STEERING MODE

Dolly movement in conventional steering mode is shown in Figs. 45 and 47A. Referring to Fig. 19 with the rackbar in the up position, the lower pin plate **160** in the rear transmission **104** is pulled into the up position. Consequently, the shift pins are aligned as shown in Fig. 19A. In this condition, none of the sprockets in the rear transmission **104** are engaged to each other. Consequently, as the handle **52** is turned, only the first center sprocket **144**, the lower sprocket **149** and the indent wheel **143** (which is driven by sprocket **59** and chain **83**) rotate, in the same direction as the handle **52**). Referring to Fig. 9, as the first center sprocket **144** turns, it drives the differential center sprocket chain **81**. This turns the right rear drive sprocket **57**, causing the right rear wheels to turn the top differential sprocket **110** (which is offset from the center sprocket **111**). The top sprocket **110** in turn drives the conventional chain **80** which turns to turning movement of the handlebar **52**.

Referring still to Fig. 9, turning the middle sprocket **111** of the differential **108** drives the left conventional chain **92**, causing the left rear drive sprocket **118** to turn in the same direction as the right rear drive sprocket **57**. However, in the conventional steering mode, the top differential sprocket **110** is off-set from the bottom sprocket **112** by a predetermined amount. This causes the inside wheels to turn more sharply as the dolly is steered around a curve, as

shown in Fig. 41. The difference in steering angle between the inside wheels and outside wheels is set by the differential so that the dolly **30** achieves near perfect geometrical steering, graphically shown in Fig. 47A. As a result, the dolly rolls silently and easily over the ground.

With constant speed turning of the handlebar **52**, the bottom differential sprocket **112** speeds up and slows down (depending on the steering angle) via the off-set of the differential sprockets **110, 111**, and **112**, to provide the different steering angles to the rear wheels necessary for conventional steering. The difference in the desired steering angle between the inside and outside rear wheels of the dolly will vary with the dolly wheel base and tread dimensions. For the dolly shown in Fig. 41, having a lateral wheel tread of 24-1/2 inches (in leg position No. 1 or 2) and a wheelbase of about 35 inches, the preferred off-set between the top and bottom sprockets of the differential for the dolly shown is about .78 inches. By comparison, for leg position No. 3, a selected offset of about .67 inches is used.

When in the conventional steering mode, the front wheels of the dolly must be locked into the straight ahead position. Referring to Fig. 19A, with the rackbar in the conventional (up) position, the shift pins in the rear transmission **104** lock the top sprocket **142** to the transmission housing. Referring to Fig. 9, consequently, the right crab chain **88** is locked in position, preventing any rotation movement of the rear transmission distributor **116**. This in turn, locks the front right chain **94** against movement, thereby locking the front right wheels into the straight ahead position.

The shift pins in the front transmission **102** operate in a similar manner, and are shifted together and simultaneously with the shift pins in the rear transmission **104**. As a result, the center sprocket **174** in the front transmission is not engaged with either the upper sprocket **172** or

lower sprocket **176** in the front transmission **102**. The center sprocket **174** can therefore turn freely with the axle **178**, when in the conventional steering mode.

Referring to Figs. 9 and 19A, the upper sprocket **172** of the front transmission **102** is locked against rotation by the shift pins engaging the upper sprocket **172** to the upper front transmission housing **106** that is bolted to the top plate **70** (similar to the locking of the top sprocket **142** in the rear transmission **104**. Referring to Fig. 9, with the top sprocket **172** locked against rotation, the front transmission distributor **115** is similarly locked against rotation by the connection of the upper sprocket **172** on the front transmission **102**, to the upper sprocket **190** on the front transmission distributor **115**, by the left crab chain **86**. As a result, the front left chain **90**, which wraps around the center sprocket **192** on the front transmission distributor **115**, cannot move.

Therefore, the front left wheel drive sprocket **126** is also locked against rotation in the straight ahead position. Hence, in conventional steering mode, the only chains that move and participate in steering are the right conventional chain **80,** the left conventional chain **92**, and the differential center sprocket chain **81**. The right rear chain **83** also moves (but does not participate, except to allow shift lock **370** to actuate) during conventional steering, because sprocket **59** is locked up with sprocket **57**, while sprocket **149** in the rear transmission, which is integral with the indent wheel **143**, spins freely. The indent wheel **143** always rotates with sprocket **149**, in all steering modes. The front wheels are locked straight ahead in conventional steering mode by the chains **90** and **94** and by the orientation of the pins in the transmission housings. This straight ahead front wheel position is adjusted during assembly of the dolly.

The steering unit is balanced in the sense that the force on the T-handle necessary to steer the dolly is the same whether turning to the left or to the right. This advantage becomes especially important when the dolly is heavily loaded (for example, with a camera operator, and a director of photography, as well as the camera, batteries, and accessories) and the steering forces needed become larger.

CRAB STEERING MODE

Dolly movement in crab steering mode is shown in Fig. 44. To shift from the conventional steering mode to the crab steering mode (or between any steering modes), the handle bar must be at 0° or 180°, causing the plunger **360** of the shift lock **370** to be withdrawn from the notch **(351-355)** in the links block **230**, as shown in Fig. 27. The links block **230** is then free to pivot. Also, the pins in the transmissions can only move when the transmission sprockets are at 0° or 180°.

The handlebar **52** is turned to 0° or 180° and is then pivoted about the B axis as shown in Fig. 2. As the handlebar **52** is pivoted into the crab position, an optional ball detent **380** (shown in Fig. 5) engages the handle housing **55** providing a tactile indication that the steering system is in the crab mode. Alternatively, the user can easily determine that the steering system has been shifted into crab mode via alignment markings on the handle **52** and handle housing **55**, or by the feel of the handle movement. The rackbar **58** is pushed downwardly by the interaction of the rack teeth **60** and the pinion gear sector **54**, shown in Fig. 5. Referring to Fig. 19A, this downward movement of the rackbar **58** in turn moves the lower pin plate **160** and the upper pin plate **168** down one position. As this occurs, the shift pins in the rear transmission **104** cause the

top sprocket **142** to engage the first middle sprocket **144**, such that sprockets **142** and **144** necessarily turn together. At the same time, the fork shaft **292** causes a similar shift in the front transmission **102**, with the result that in the front transmission the upper sprocket **172** is locked together with the center sprocket **174** by the shift pins in the front transmission.

Referring to Fig. 33, as the rear fork **302** is pushed downwardly by the pin plate rod **162** in the rear transmission **104**, the rear fork **302** drives the transmission linkage **236** which includes the fork shaft **292** and the front fork **294**. In addition, this movement of the rear fork **302** during shifting from the conventional to crab mode (via turning the handlebar **52**) also simultaneously causes the arm **304** on the rear fork **302** to drive the ball clevis **306**. This in turn drives the rear link **310**, and in turn the shift link **318** and lever **320**, causing the links block **230** to rotate by a predetermined amount, as shown in Fig. 34.

Referring to Fig. 7, 10 and 39, this movement of the links block **230** causes the top differential sprocket link **250** to shift in a direction towards aligning the top sprocket **110**, the middle sprocket **111**, and the bottom sprocket **112** of the differential. Simultaneously, the other four links attached to the links block **230** move the active idlers **99, 76, 77** and **75**. The center differential plate **209** also moves along with the parallelogram-like links **240, 244** and **248** and **245** on the opposite side of the differential. This shifting causes the top differential sprocket **110**, the middle differential sprocket **111** and the bottom differential sprocket **112** to align with each other (and correspondingly, the plates **205, 209** and **207** are also aligned). The differential **108** then no longer provides any steering angle correction or difference between the left and right rear wheels. Rather, in the crab mode, the differential **108** acts likes a simple distributor, i.e., with the top, middle and bottom sprockets aligned on a common shaft.

During this shifting motion, the rollers **218** roll in the slots **210** in the top and bottom differential plates **205** and **207**. The rollers **218** transmit torque between the top and bottom sprockets of the differential **108**, yet allow those sprockets to be off-set from each other, in conventional and round steering modes.

Referring to Figs. 9 and 19A, with the steering system **50** shifted into the crab steering mode, movement of the handle tube **56** turns both the top sprocket **142** and first center sprocket **144** in the rear transmission. As a result, the right crab chain **88** passing around the top sprocket **142** drives the top sprocket **120** on the rear transmission distributor **116**. This causes the entire rear transmission distributor **116** to turn, including the center sprocket **122** and lower sprocket **124** on the rear transmission distributor **116**. The turning movement of the lower sprocket **124** drives the front right chain **94**, causing the front right drive sprocket **128** and the front right wheels to turn with the handle tube **56**. The center sprocket **122** on the rear transmission distributor **116** also turns, driving the round drive chain **82** around the fixed idlers **96** and **98**, and around the free spinning lower center sprocket **146** on the rear transmissions **104**. This movement does not participate in any steering, in the crab mode.

Referring still to Fig. 9, with the steering system **50** in the crab steering mode, the upper center sprocket **144** on the rear transmission **104** also turns with turning movement of the steering tube **56**. This movement drives the differential center sprocket chain **81**, thereby driving the right conventional chain **80** through the top differential sprocket **110** (in the same direction and speed as the chain **81**). The chain **80** then turns the right rear drive sprocket **57** and the right rear wheels of the dolly **30**, in the same direction, and by the same amount as the front right wheels. The chain **81** also drives the now aligned lower differential sprocket **112**. The bottom

differential sprocket **112** then drives the left conventional chain **92**, turning the left rear wheel sprocket **118**, and therefore the left rear wheels.

Referring still to Fig. 9, the movement of the left conventional chain **92** also turns the center sprocket **174** on the front transmission **102**. As the center sprocket **174** is locked into engagement with the top sprocket **172** in the front transmission **102** by the shift pins, the right crab chain **86** correspondingly drives the entire front transmission distributor **115**. The center sprocket **192** on the front transmission distributor **115** drives the front left chain **90**, turning the left front drive sprocket **126**, and the front left wheels.

Thus, when in crab mode, all of the wheels turn in the same direction, and by the same amount, with turning of the T-handle. The turning movement of the front transmission distributor **115** also drives the round left chain **84**. However, the chain **84** does not participate in steering in the crab steering mode, as sprocket **176** is free turning in the crab mode.

The diameters of the various sprockets in the steering system **50** are selected to provide a 1:1 ratio between turning movement of the handle tube **56** and the turning movement of the wheels, in the crab mode. Accordingly, as described above, in the crab steering mode, all of the wheels of the dolly are steered in the same direction and by the same amount, as shown in Fig. 44.

ROUND STEERING MODE

Dolly movement in round steering mode is shown in Figs. 43 and 47B. To shift from the crab steering mode to the round steering mode, the handlebar **52** is rotated about the B axis to a third (down) position. As shown in Fig. 5, this movement of the handlebar **52** further drives the

rackbar **58** downwardly. As a result, the upper pin plate **168** and the lower pin plate **160** in the rear transmission **104** are moved down into their lowest operating position (for round steering). The shift pins are also pushed down, by the upper pin plate locking the lower sprocket **146** to the bottom sprocket **144** in the rear transmission **104**. At the same time, upper pin plate **189** and the lower pin plate **187** in the front transmission **102** also move downwardly, and cause the shift pins in the front transmission **102** to lock the lower sprocket **176** to the center sprocket **174**.

Referring to Figs. 7, 19 and 33-35, the downward shift of the rackbar **58** drives the pin plate rod **162** to its lowest position. At the same time, the rear fork **302** is pivoted further downwardly causing the arm **304** to drive the over center linkage **300** into the round steering position. With this movement, the rear link **310** in the over center linkage **300** moves through a center position, pulling the connecting link **318** forwardly. As a result, the links block **230** pivots (in the direction substantially opposite to the turning movement when shifting from conventional to crab steering). Referring to Fig. 7, as the links block **230** pivots (clockwise, when viewed from above), the top step link **250** moves the top differential sprocket **110** away from the bottom differential sprocket **112**. Simultaneously, the links **250, 248, 244, 240,** and **245** move the center differential plate **209** off center from the bottom differential sprocket **112,** to the positions shown in Figs. 7 and 41. This is the maximum off- set position of the differential **108**.

The amount of offset in the differential **108** for round steering is double the off-set for conventional steering. As the top differential sprocket **110** moves off -center, the tension in the right conventional chain **80** must be maintained. This is achieved via the active idlers **76** and **99**. As shown in Fig. 9, the active or moving idlers **76** and **99** both engage the right conventional chain **80** on opposite sides of the top differential sprocket **110**. During movement of the links

block **230** into the round steering mode, the short link **280**, which controls the position of the active idler **76**, and the to link **260**, which controls the position of the active idler **99**, both shift to maintain appropriate tension on chain **80**. The active idlers also perform this function when shifting between conventional and crab steering.

Referring once again to Fig. 9, with the first or upper center sprocket **144** locked together for rotation with the bottom sprocket **149** of the rear transmission **104**, turning movement of the handle tube **56** drives the differential center sprocket chain **81**, thereby turning all of the differential sprockets (by different amounts due to the sprocket offsets). The top sprocket **110** drives the right conventional chain **80**, steering the right rear wheels. The lower differential sprocket **112**, which is now off-set from the upper differential sprocket **110** by a maximum off-set distance also turns, driven by chain **81** and by the rollers **218** driving the plates **205, 207**. The off-set amount is sufficiently large enough to drive the left rear wheels to a steering angle, relative to the right rear wheels, such that the rotation axes of the left and right rear wheels intersect at a point along the center axis of the dolly **30**, as is necessary for round steering. This off set in steering angles between the rear wheels is achieved via the differential **108**, with the chains **80** and **92** and sprockets **57** and **118** turning in the same direction. Due to the offset, the chains controlling the wheels steering angle speed up and slow down, in a sine function, relative to the turning of the T-bar, so that each wheel is turned to the correct angle.

Referring still to Fig. 9, as the lower center sprocket **146** of the rear transmission **104** turns, the outside or rear surface of the round drive chain **82** turns the rear transmission distributor **116** in a direction opposite to the turning direction of sprocket **146**. The lower sprocket **124** on the rear transmission distributor **116** consequently drives the front right chain **94**

and sprocket **128** in a direction, and to a steering angle, equal to and opposite from the right rear drive sprocket **57**. The lower differential sprocket **112** drives the left conventional chain **92**, thereby turning the center sprocket **174** in the front transmission **102**. The center sprocket **174** is secured to and turns the lower sprocket **176** of the front transmission, driving the left round chain **84**. As the lower sprocket **194** on the front transmission distributor **115** engages the outside or back surface of the round left chain **84**, the entire front transmission distributor **115** is turned in a direction opposite to the direction of rotation of the center and lower sprockets **174** and **176** of the front transmission **102**. As a result, the front left chain **90** turns the front left wheel drive sprocket **126** in a direction opposite to the turning movement of the left rear wheel sprocket **118**. Consequently, the front left and rear left wheels of the dolly are steered in equal and opposite directions, such that their axes of rotation also intersect the axes of rotation of the rear right and front right wheels, at a single point P, as shown in Fig. 43. In this round steering mode, the dolly can turn about the center of its wheelbase, allowing for minimum turning radius and greater maneuverability.

As shown in the drawings, some of the chains wrap around a sprocket for only a short distance, providing only a minimal engagement between the sprocket teeth and chain links. To prevent the chain from inadvertently skipping over sprocket teeth, during high torque maneuvers, chain guards are preferably provided. Referring to Fig. 11A, a first chain guard **322** is attached to the bottom surface of the sprocket link **250**. The inside surface of the first chain guard **322** is contoured to match the curvature of the upper differential sprocket **110** with the left conventional chain **80** wrapped around it. The chain guard **322** is positioned sufficiently close to the chain **80** to prevent it from rising up and skipping over teeth on the sprocket **110**. Second and third chain

guards **324** and **326**, as shown in Figs. 12 and 13, are similarly provided to prevent skipping of the round left chain **84** over the sprocket **194** on the front transmission distributor **115**, and to prevent the round drive chain **82** from skipping over the teeth on the sprocket **122** of the rear transmission distributor **116**. A rear transmission chain guard **390** may also be provided, as shown in Fig. 2.

During initial alignment of the steering system, the alignment pin **213** is placed through a hole in the top plate **70** and through the alignment holes **212** in the differential **108**, as shown in Fig. 21, with the steering system in the crab mode. If necessary, the top, middle and bottom differential sprockets, and all of the sprockets on both distributors, can also be adjusted (i.e., turned in either direction and then locked in place). The chains of the steering system are then adjusted using the various fixed idlers. The steering system is then ready for installation into a dolly.

Turning to Fig. 48, in an alternative embodiment **400**, the camera dolly **30** is provided with a servo assist system **402**. The servo assists system **402** includes motors **404**, preferably electric motors, which are mechanically linked into the steering system **50**, to reduce the amount of torque needed at the steering handle bar **52**, to steer the dolly. The output shaft of each motor **404** is advantageously connected, optionally through a gear reduction unit or belt drive, to the wheel pair adjacent to the motor **404**. At the rear of the dolly, the motor **404** is linked to the axle **53**. At the front of the dolly, a motor **404** is similarly linked to a wheel drive sprocket **126** or **128**. Consequently, torque exerted by the motors is transferred to the kingpins **47** on which the wheels are mounted.

The motors **404** are connected to a controller **408** via control line **414**. The controller **408** is connected to a power source **410**, such as a battery or power supply. The controller preferably includes encoders to sense the wheel angles, via the positions of the belts, or via sensors at the kingpins, or at the axles **53** and drive sprockets.

In use, the servo assist system is used when the dolly is round or in crab steering mode, to reduce the steering effort needed at the handle bar **52**. At certain positions, selected wheels have to spin faster than other wheels, to maintain proper steering geometry, especially at sharp steering angles. These fast wheel turning movements require higher levels of torque. The controller detects these conditions and energizes the motors, in the proper directions, and the proper speeds, to assist in steering, and reduce the torque which the dolly operator must exert at the handle **52**. High steering loads may also be encountered when the dolly is very heavily loaded, or is on a resistant surface, such as carpeting.

In a modified design, the motors driving the steering of the back wheels may be omitted, with motors providing power assist only for the front wheels.

The servo assist system may also be powered hydraulically, rather than electrically. In a hydraulically powered system, hydraulic motors are used instead of electric motors. The hydraulic motors are connected to the accumulator in the dolly's hydraulic arm system. Belt tension or force and movement is detected via encoders linked to hydraulic valves. The valves open and close to control direction and speed of movement or torque boost provided.

Alternatively, a simplified system utilizing microswitches on the handle **52** may be provided. Pressure to torque the steering handle closes microswitches **420**, as shown in Fig. 6, to complete the circuit to the appropriate motors **404** to provide power to help rotating kingpins.

This system coupled with the belt connecting the motors to appropriate kingpins provides for easy control of steering even in difficult situations, providing a low cost way to add a power steering system to the dolly.

Thus, a novel camera dolly has been shown and described. Various modifications and substitutions of known equivalents may of course be made, without departing from the spirit and scope of the invention. For example, belts or gears may be substituted for chains, pulleys and gears may be substituted for sprockets, and the components and functions of various elements of the steering unit may be combined in ways different from those shown and described. The invention, therefore, should not be limited, except by the following claims and by equivalents to the claims.